

Agriculture

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- Higher Crop Production

- Fertilizer:

- Label (tracer property) to determine optimal effectiveness
 - Minimize fertilizer needed

- Water:

- Neutron moisture gauges to determine proton content (moisture)

• Higher Crop Production (cont.)

New Species: *The biggest impact of radiation to Agriculture*

- Selective breeding from spontaneous mutations previously used to winnow out weaker plant species
- Radiation can be employed to break bonds to rapidly create new combinations in genetic makeup (**mutant varieties**)
 - **Increased crop yields (reduced fertilizer use)**
 - **Better disease, pest, & draught resistance (less pesticides & water)**
 - Enhanced maturing times (allows crop rotation)
 - Improved nutritional value
 - Improved quality
 - Improved processing quality
 - Enhanced customer acceptance
 - Color; flavor

> 30 nations have developed ~ 2250 new crop varieties (radiation used in 89% of these!)

History of Radiation in Crop Development

- 1928 – Discovery of Mutagenesis
(most important tool for locating genes on chromosomes)
- Plant breeders and geneticists interested in radiation as fast & effective way to alter plant traits
- Over 30 countries now use mutant varieties
- Over 60% of present 2250 varieties released since 1985
- Most prominent are
 - China (26.8%)
 - India (11.5%)
 - USSR/Russia (9.3%)
 - The Netherlands (7.8%)
 - USA (5.7%)
 - Japan (5.3%)

Forms of Radiation Used

- Of all the crop mutations in present use,
89% derived from radiation processes
(remainder are primarily chemical)
 - 64% via gamma rays
 - 22% via x-rays
 - Remainder from fast and thermal neutrons
(and other radiation)

Mutant Varieties (cultivars)

Grains: Rice, barley, wheat, beans, lentils, peas, ...

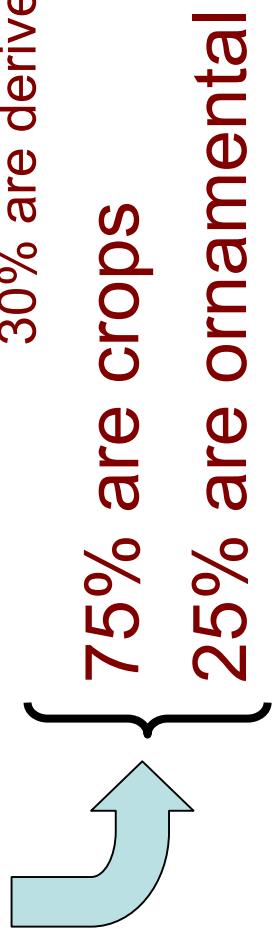
Other Crops: Cotton, soybeans, peppermint, ...

Fruits: Apples, cherries, oranges, peaches, grapefruit, ...

Flowers: Chrysanthemums, roses, dahlias, ...

Of the 2250 cultivars, 70% are direct mutants

30% are derived from mutant parents



Rice

- Rice is the major source of food for over 50% of the global population—especially in Asia
- 434 mutant varieties (one half from gamma radiation)
- **Egypt:** Semi-dwarf varieties increased average production to 8.9 t/ha (compared to 3.8 t/ha world average), i.e. double!
- **Japan:** 18 mutant varieties → \$927M in 1997
- **Thailand:** Largest exporter of aromatic rice in the world
From 1989 to 1998, produced \$16.9B of milled rice!

Barley

- Short-height & high yield ‘Diamant’ & ‘Golden Promise’ mutants
- Major impact to European brewing & malting industry
- UK & Ireland used ‘Golden Promise’ widely for beer & whiskey (1960s & 1970s)
- Scotland: Premium quality ales & whiskey
 - \$417M over last quarter century

Wheat

- **Italy:** 1974, Durham wheat ‘Creso’ mutant developed
 - By 1984, this mutant reached 53.3% of Italian market
 - \$180M/year (\$1.8B in single decade)

Over 50% of Pasta in Italy due to radiation!

- **Pakistan:** 3 mutant varieties have provided \$47M to farmers in 5-year period

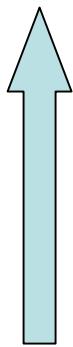
Cotton

- **Pakistan:** High-yielding cotton mutant NIAB-78
 - Produced by gamma rays
 - Released in 1983
 - Shorter stature, better growth, heat tolerant, resistant to bollworm attack due to early maturity
 - Ideal cotton-wheat rotation planting
- **Marked influence in sustaining Pakistan textile industry (whole industry threatened by insects)**
 - Within 5 years of release, Pakistan cotton production **doubled!**
 - Within 10 years of release, over \$3.0B in cotton production

Peppermint

- Peppermint plant:
 - USA produces 90% of world's peppermint oil
 - Fungus disease threatened extinction (Verticillium wilt)
 - All cross breeding efforts failed
 - Radiation bombardment led to 2 successful new varieties (neutrons & x-ray treatments)
(saving the original peppermint taste!)

\$930M annual value in USA



Grapefruit

- ‘Star Ruby’ mutant released in Texas in 1970
 - Achieved by thermal neutron irradiation
 - Seedless, red flesh, widely accepted
 - But, yield was variable
- ‘Rio Red’ mutant released in 1984
 - Achieved by thermal neutron irradiation of ‘Star Ruby’
- Both now sold under trademark ‘Rio Star’
 - Now grown on 75% of the grapefruit production area of Texas (7300 ha)

Japanese Pear

- Original species susceptible to blackspot disease
- ‘Gold Nijiseiki’ developed via gamma rays
- Additional income from this cultivar ~\$30M/yr

NOTE: Overall additional income in Japan from radiation in agriculture in 1997 was \$973M/yr (including rice, peas, soybeans & peaches)

Flowers

- **522** mutant cultivars recorded by year 2000
 - However, many not counted
 - Commercial companies keep much of this as trade secret—and do not report
- **Goals:** Change flower color, shape, size, shelf life
 - Sometimes select cultivar with pink flowers, and then irradiate the cuttings to get red, white, & yellow mutants
- **Major Varieties:**
 - Chrysanthemums (232)
 - Rose (61)
 - Dahlia (36)
 - Alstroemeria (35)
 - Streptocarpus (30)
 - Begonia (25)
 - Carnation (18)
 - Azalea (15)
 - Bougainvillea (12)
 - Achimenes (8)

• Improved Animal Production

– Nutrition:

- Labeling food with C-14 allows tracing specific food products throughout the digestive system
- Example: Multi-nutrient lick block for buffalos in Indonesia
 - Increased weight gain at rate of 3 Kg/week
 - Reduced grass consumption by 80%

- ## Eradication of Pests

- Chemical Treatments:
 - Create environmental pollution
 - Toxic residues remain in food chain
 - Insects develop tolerance to insecticides
 - Requiring increasingly higher doses
- Sterile Insect Technique (SIT)
 - Produce or capture large numbers of insects and sterilize them
 - Release them into their native environment
 - No offspring!
 - Tsetse fly eradicated in parts of Africa (allowing human settlement)
 - Other examples: Mediterranean fruit fly, Mexican fruit fly, Boll Weevil

- **Improved Food Safety**

- Magnitude of Problem
 - Infestation & spoilage prevents ~ 50% of food grown in many parts of the world to be wasted
 - Spoilage of sea food sometimes as high as 90%
 - In the United States **every year**
 - Over 76,000,000 cases of food poisoning
 - Over 325,000 hospitalizations
 - Over 5,000 deaths
- Historic Food Preservation Techniques
 - Sun drying
 - Smoking
 - Heating
 - Salting
 - Canning
 - Freezing
 - Chemical treatments (e.g. methyl bromide)

- ## Food Irradiation

- Beta particles or gamma rays will kill bacteria & pathogens by breaking DNA bonds
 - (particularly effective during reproductive cycle)
- Specific pathogens targeted include:
 - *Salmonella*
 - *E-coli (0157:H7)*
 - *Listeria monocytogenes*
- NOTE: Goal is not to totally eliminate contamination
 - Some pathogens necessary in body to stimulate immune system
 - ~5 orders of magnitude reduction generally sufficient

- **Status of Food Irradiation**

- Studied for over 40 years
- Over 36 nations produce some irradiated food
- Approved by wide body of scientific bodies;
 - World Health Organization
 - American Medical Association
 - etc.
- United States status
 - FDA approval for spices, poultry, red meat, ...
 - Fish and prepared products still pending
 - Used by astronauts, open heart patients, etc.

- **New Food Irradiation Center at Texas A&M**
 - Three state-of-the-art accelerators
 - **2 – 10 MeV, 18 kW vertical linear accelerators (beta)**
 - **1 – 5 MeV, 15 kW horizontal linear accelerator (x-ray)**
 - **30,000 ft² of research & production space**
 - **Located in research park adjacent to campus**
 - Joint venture with SureBeam Corporation
 - 10-year agreement
 - **Operational summer of 2002**
 - Research will include a focus on
 - **Food borne human pathogens**
 - **Food quality**
 - **Food packaging**
 - **Food formulation**
 - **Electron deposition and dosimetry**

Grand Opening of Texas A&M Food Irradiation Research Center, March 4, 2002



Cost-Benefit Aspects of Food Irradiation Processing

IAEA Symposium, Aix-en-Provence, France

March 1993

- 1. Health & economic costs of foodborne diseases are not well recognized by most governments**
- 2. Governments are urged to adopt broad regulations based on the principles of the Codex General Standard for Irradiated Foods**
- 3. Governments are urged to accept food irradiation as an alternative to fumigation**
- 4. The private sector should become involved**
- 5. Additional radiation processing capacity will be needed by the food industry in the near future**
- 6. All parties (governments, professional organizations, the food industry, etc.) should make greater efforts in disseminating accurate information on the cost & benefits of irradiation**
 - Reduce food losses
 - Reduce foodborne diseases
 - Expand food trade

Benefits of Radiation to Japanese & USA Agriculture (1997)

	Annual Direct Revenue (\$B)	
	<u>JAPAN</u>	<u>USA</u>
Crop Mutation	0.804	11.2
Sterile Insect Technique	0.069	
Packaging for Food	0.051	
Food Irradiation	0.016	3.2
Other R&D	<u>0.024</u>	
TOTAL =	0.964	14.5